

[illegible]

**National  
Defence**

Défense  
nationale

DTIC

ELECTR

FEB 1 1993

C

# THE NEW DREO MOBILE NUCLEAR LABORATORY (U)

by

T. Cousins and B.E. Hoffarth

ALL INFORMATION CONTAINED  
HEREIN IS UNCLASSIFIED  
DATE 08-22-2011 BY 60322 UCBAW

**DEFENCE RESEARCH ESTABLISHMENT OTTAWA**  
**TECHNICAL NOTE 92-6**

# Canada

January 1992  
Ottawa



National  
Defence

Défense  
nationale

Acquisition For	
NTIS	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

DTIC QUALITY INSPECTED 3

# THE NEW DREO MOBILE NUCLEAR LABORATORY (U)

by

**T. Cousins and B.E. Hoffarth**  
*Nuclear Effects Section  
Electronics Division*

**DEFENCE RESEARCH ESTABLISHMENT OTTAWA**  
TECHNICAL NOTE 92-6

PCN  
031LE

January 1992  
Ottawa

**93-01706**



93 1 20 060

## **ABSTRACT**

The new DREO Mobile Nuclear Laboratory (MNL) has just recently completed successful field trials. The capabilities of the new MNL are examined, and seen to be far superior to its predecessor. This lab will help keep DREO at the forefront of nuclear radiation research within the NATO community for many years to come, as well as providing the DND Nuclear Emergency Response Team (NERT) with unique capabilities in the event of any crisis.

## **RESUMÉ**

Les essais du nouveau laboratoire nucléaire mobile (LNM) du CRDO ont été récemment complétés. Les capacités du nouveau LNM ont été examinées et jugées très supérieures à celle des modèles précédant. Ce laboratoire permettra au CRDO de se maintenir pour plusieurs années à la fine pointe de la recherche sur les radiations nucléaires parmi ses partenaires de l'OTAN, ainsi qu'il mettra à la disposition de l'équipe d'intervention d'urgence nucléaire du MDN un outil unique dans les cas de crises.

## EXECUTIVE SUMMARY

The new DREO Mobile Nuclear Laboratory (MNL) has just recently completed successful field trials. The capabilities of the new MNL are examined, and seen to be far superior to its predecessor. This lab will help keep DREO at the forefront of nuclear radiation research within the NATO community for many years to come.

## TABLE OF CONTENTS

ABSTRACT .....	iii
RESUMÉ .....	iii
EXECUTIVE SUMMARY .....	v
TABLE OF CONTENTS .....	vii
LIST OF FIGURES .....	ix
LIST OF TABLES .....	xi
1.0 INTRODUCTION .....	1
2.0 THE NEW MNL .....	2
2.1 Physical Description .....	2
2.2 The New MNL - Experimental Capabilities .....	2
2.3 Applicability of New MNL .....	5
3.0 CONCLUSIONS .....	5
4.0 REFERENCES .....	12

## LIST OF FIGURES

Figure 1:	Old (right) and new (left) MNLs at DREO Note the important difference in length.	7
Figure 2:	Measured neutron energy spectra at NATO standard reference point (400m) at Aberdeen Proving Ground. The figure is illustrative of the relative energy ranges and resolutions for the various MNL detectors.	8
Figure 3:	BGO-measured gamma-ray energy spectrum in the area above the RMC SLOWPOKE II facility. Note the presence of peaks (due to neutron capture) riding on a continuum.	9
Figure 4:	Gamma-ray dosimetric capabilities of DREO TLD systems. A 'perfect' dosimeter here would have a flat (=1) response, with small error bars. Note that with $Al_2O_3$ the measurable limit (defined as 10% accuracy) has been reduced from ~ 10 mRad to ~ 0.2 mRad.	10
Figure 5:	ATR5 output prediction of prompt nuclear radiation from a 10kT standard fission weapon.	11
Figure 6:	'Weapons Effects' output prediction of long-range fallout from a 1 MT standard fission weapon.	12

## LIST OF TABLES

Table 1:	Physical Parameters of MNLS	2
Table 2:	Dosimetry Capabilities	3
Table 3:	Spectroscopy Capabilities	4
Table 4:	Available Relevant Computer Codes in New MNL	5

## 1.0 INTRODUCTION

The Mobile Nuclear Laboratory (MNL) has for the past 10 years played a major part in the radiation shielding and dosimetry project within the Nuclear Effects Section (NES) at Defence Research Establishment Ottawa (DREO). The MNL provides a self-powered mobile facility capable of on- and off-site data acquisition and analysis pertaining to neutron and gamma-ray radiation fields. Among the many tasks the MNL was required to support were:

- (1) On-site experiments involving DREO staff and visiting scientists;
- (2) Measurement of radiation fields at other Canadian and foreign experimental facilities;
- (3) Provision of scientific advice for any nuclear incident in which DND (or other) personnel were possibly at risk.

The original MNL performed these tasks well, but suffered from some shortfalls relating to its ten-year-old technological base. Perhaps chief among these shortfalls was its large size, necessitated primarily by its mainframe (PDP 11/34) computer system used for almost all data acquisition and analysis. This large physical size meant that the old MNL was not transportable by CF Hercules, and that the MNL could not participate directly in planned experiments in France, the COSMOS 954 re-entry project or the post-Chernobyl evaluation at CFB Lahr, FRG, all of which required NES staff. The old MNL was also required at DRES for radioactive contamination evaluation (1), and this lack of an air-transportable lab caused considerable delay.

For these, and other reasons it was decided in 1990 to replace the old MNL with a newer, smaller vehicle which would take advantage of smaller and more powerful modern computers. A considerable reduction in the overall vehicle dimensions is achieved, allowing air transport. Although more compact, the new MNL is much more versatile and capable than its predecessor, as will be pointed out in the balance of this report. The new MNL successfully completed its first field trial in June 1991 at Royal Military College, Kingston (2).

## 2.0 THE NEW MNL

### 2.1 Physical Description

Table (1) lists some relevant physical parameters comparing the old and new MNLs.

**TABLE (1)  
PHYSICAL PARAMETERS OF MNLs**

	<u>Old</u>	<u>New</u>
Overall length	30'2"	23'9"
Overall height		
- with A/C	10'2"	9'9"
- without A/C	8'11"	8'7"
Overall width	7'11"	7'11"
Office/lab space l×w×h	18'2"×7'7"×6'3"	11'8"×7'7"×6'2"
storage space l×w×h (some taken up by generators)	5'3"×7'7"×6'3"	4'4"×7'7"×6'2"
Gross Vehicle Weight	19,500 lbs.	15,500 lbs.
Generators	two 6 kW	two 6 kW

Fig (1) shows the old and new labs back-to-back to put the numbers in perspective.

### 2.2 The New MNL - Experimental Capabilities

The dosimetry and spectroscopy capabilities of the new MNL are compared to the old MNL in tables (2) and (3) below. The complete set of equipment listed here may be carried at one time, and indeed is necessary for many applications. The designations in the left-hand column indicate whether a system is used in the old MNL, the new MNL or both.

The gamma-ray spectrometers are divided into 'field' and 'contamination/lab' types. A 'field' spectrometer is normally deployed at some distance, typically 100', from the MNL, and measures free-in-air spectra either from a (experimental) long-range radioactive source or distributed ground contamination. A 'lab-contamination' spectrometer is one which is fixed (either in the MNL or some other laboratory) and receives possibly radioactive samples which are then counted for (induced) radioactivity. Note here that either BGO or NaI(Tl) could be used as a 'lab-contamination' spectrometer, but the Ge detector (having much superior resolution) is the preferred choice. The idea of a 'field' Ge spectrometer is currently being investigated by NES.

Note that normally there is no need for a 'lab-contamination' neutron spectrometer. However, should the occasion arise (delayed neutron monitoring, etc.) the ROSPEC would be ideally suited.

**TABLE (2)**  
**DOSIMETRY CAPABILITIES**

(a) Gamma-Ray Dosimetry

<u>Lab</u>	<u>System</u>	<u>Reference</u>	<u>Measurable Dose/ Dose Rate Range</u>
Old + New	CaF <sub>2</sub> :MN TLDs [Harshaw Reader]	(3)	10 mRad - few MRad
Old + New	Eberline ASP-1 Hand held Geiger Monitor	(1)	Background - few Rads/h
New	Al <sub>2</sub> O <sub>3</sub> TLDs [Harshaw Reader]	(4)	0.2 mRad - few kRads

(b) Neutron Dosimetry

<u>Lab</u>	<u>System</u>	<u>Reference</u>	<u>Measurable Dose Range</u>
Old + New	BD100R Bubble Detectors + reader	(3)	Background - 1 Rad
New	'TREE' Bubble Detector + Reader	(5)	1 Rad - 100 Rad
New	Rh - foil activation system	(6)	1 Rad - many kRad

Note: Both vehicles are capable of carrying the Humanoid RT-200 anthropomorphic phantom for internal dosimetric mapping. The extended capabilities of the new MNL make this type of work much simpler to perform and more accurate.

**TABLE (3)**  
**SPECTROSCOPY CAPABILITIES**

**Gamma-Ray Spectroscopy**

(a) Field Spectroscopy

<u>Lab</u>	<u>System/Computer- Data Analysis System</u>	<u>Reference</u>	<u>Measurable Energy Range</u>
Old	BGO/PDP 11-34	(7)	0.1 MeV - 12 MeV
New	BGO/Canberra PC		

(b) Lab/Contamination Spectroscopy

<u>Lab</u>	<u>System/Computer- Data Analysis System</u>	<u>Reference</u>	<u>Measurable Energy Range</u>
New	Ge (High Resolution) Aptec PC	(1)	0.05 MeV - 4 MeV

**Neutron Spectroscopy**

<u>Lab</u>	<u>System/Computer- Data Analysis System</u>	<u>Reference</u>	<u>Measurable Energy Range</u>
Old	NE213/BF <sub>3</sub> /PDP11-34	(7)	0.7 MeV - 16 MeV directly
New	NE213/Canberra PC BF <sub>3</sub> /Compaq PC		thermal to 0.7 MeV inferred
New	ROSPEC/BTI PC	(7)	0.06 MeV - 4.5 MeV
New	Bubble Spectrometer & Reader	(8)	0.01 MeV - 20 MeV

Figs. 2-4 illustrate some of these spectroscopic and dosimetric capabilities.

## 2.3 Applicability of New MNL

To illustrate some possible uses of the new MNL a variety of scenarios are discussed below, together with the equipment which would be best suited to serve the CF in each.

### a. Long Duration or Very-Low Level Exposures

The new International Commission on Radiation Protection (ICRP) dose limits (recently agreed to by Atomic Energy Control Board of Canada) are 2 Rad/y for radiation workers and 0.1 Rad/y for non-radiation workers. This last value is of the order of the ambient background radiation levels (roughly 50% of which is gamma-ray).

In any event it is clear that dose rates of the order of  $\mu\text{Rad/h}$  -  $\text{mRad/h}$  must be accurately measured to ensure absolute compliance. The clear dosimetric choice would be  $\text{Al}_2\text{O}_3$  TLDs and bubble detectors. All spectrometers mentioned in the table will operate in the  $\text{mRad/h}$  range.

### b. Accident Scenarios

For all accidents (including criticality) the fields are in general unknown and may fluctuate widely. Thus the entire gamut of doses from background up to lethal ( $\sim 450$  rads) and above must be measurable. For dosimetric purposes a combination of  $\text{Al}_2\text{O}_3$  and  $\text{CaF}_2\text{Mn}$  TLDs coupled with bubble detector/Rh-foils would constitute the optimum criticality dosimetric system. All spectrometers, save the bubble spectrometer will not operate above a few  $\text{mrad/h}$  due to dead-time effects, and thus accurate dosimetry before spectroscopy is essential.

### c. TREE Experiments

In support of Transient Radiation Effects on Electronics (TREE) experiments neutron fluences of  $10^{12}\text{n/cm}^2$  ( $\sim 1000$  Rads), gamma-ray doses of 1000's of Rads and dose rates of  $10^9$  Rads/s must routinely be measured - although a few percent of these values can sometimes be obtained by facility adjustment. Thus  $\text{CaF}_2\text{:Mn}$  TLDs and Rh-foils and bubble detectors and spectrometers are the choices here.

### 3.0 CONCLUSIONS

The new DREO mobile nuclear laboratory is a unique facility capable of neutron and gamma-ray dosimetry, spectroscopy and calculations, either on or off-site, at an extremely high (scientific) level. The new lab is more compact (and thus, transportable) than its predecessor, while at the same time offering much greater technical capabilities and accuracy. The new MNL will be able to serve DND's needs in nuclear radiation research, accident and weapon scenarios for many years to come.



Figure 1: Old (right) and new (left) MNLs at DREO  
Note the important difference in length.

# MEASURED ENERGY SPECTRA 400 m

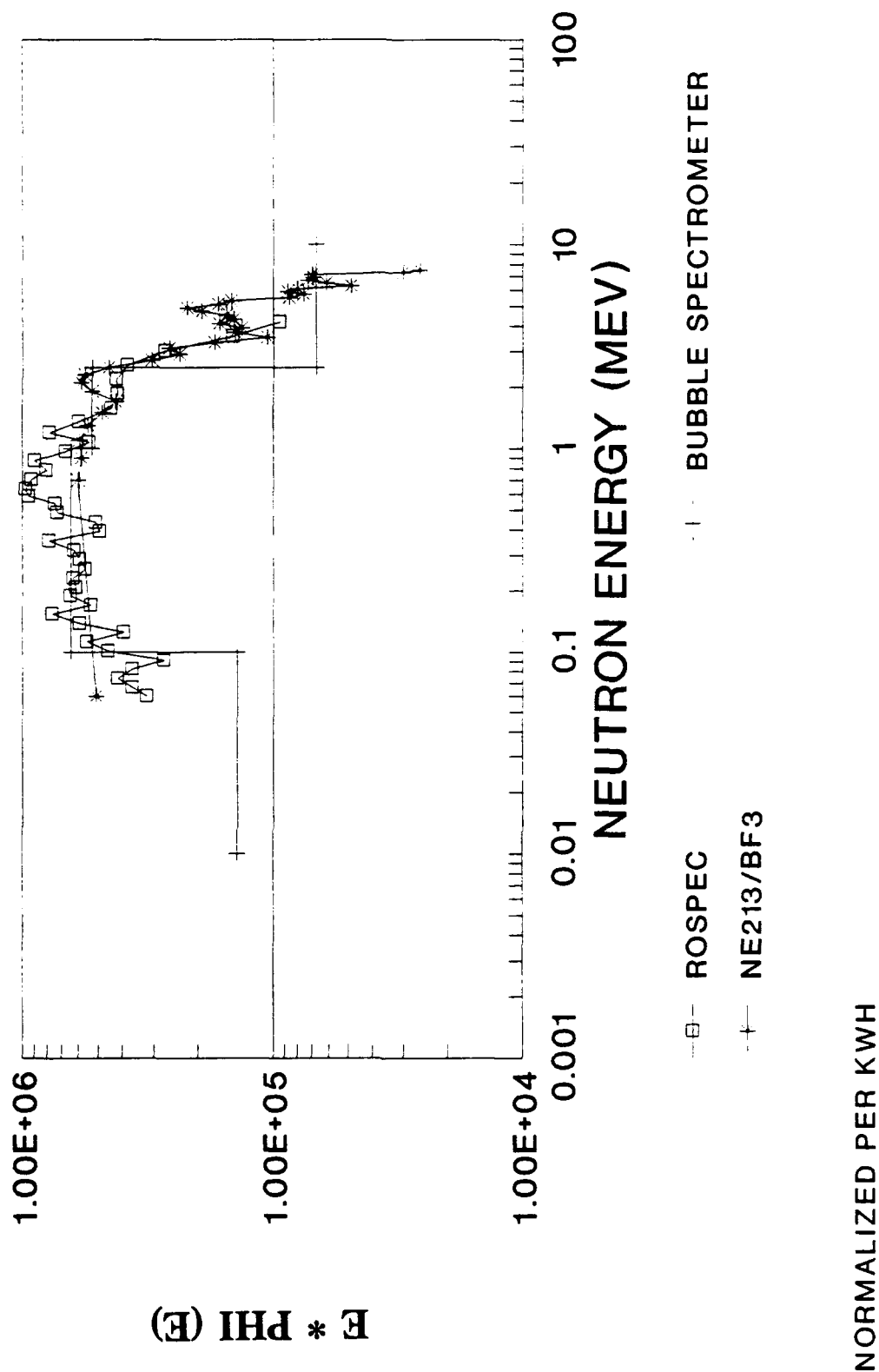


Figure 2: Measured neutron energy spectra at NATO standard reference point (400m) at Aberdeen Proving Ground. The figure is illustrative of the relative energy ranges and resolutions for the various MNL detectors.

# BGO GAMMA-RAY SPECTRUM

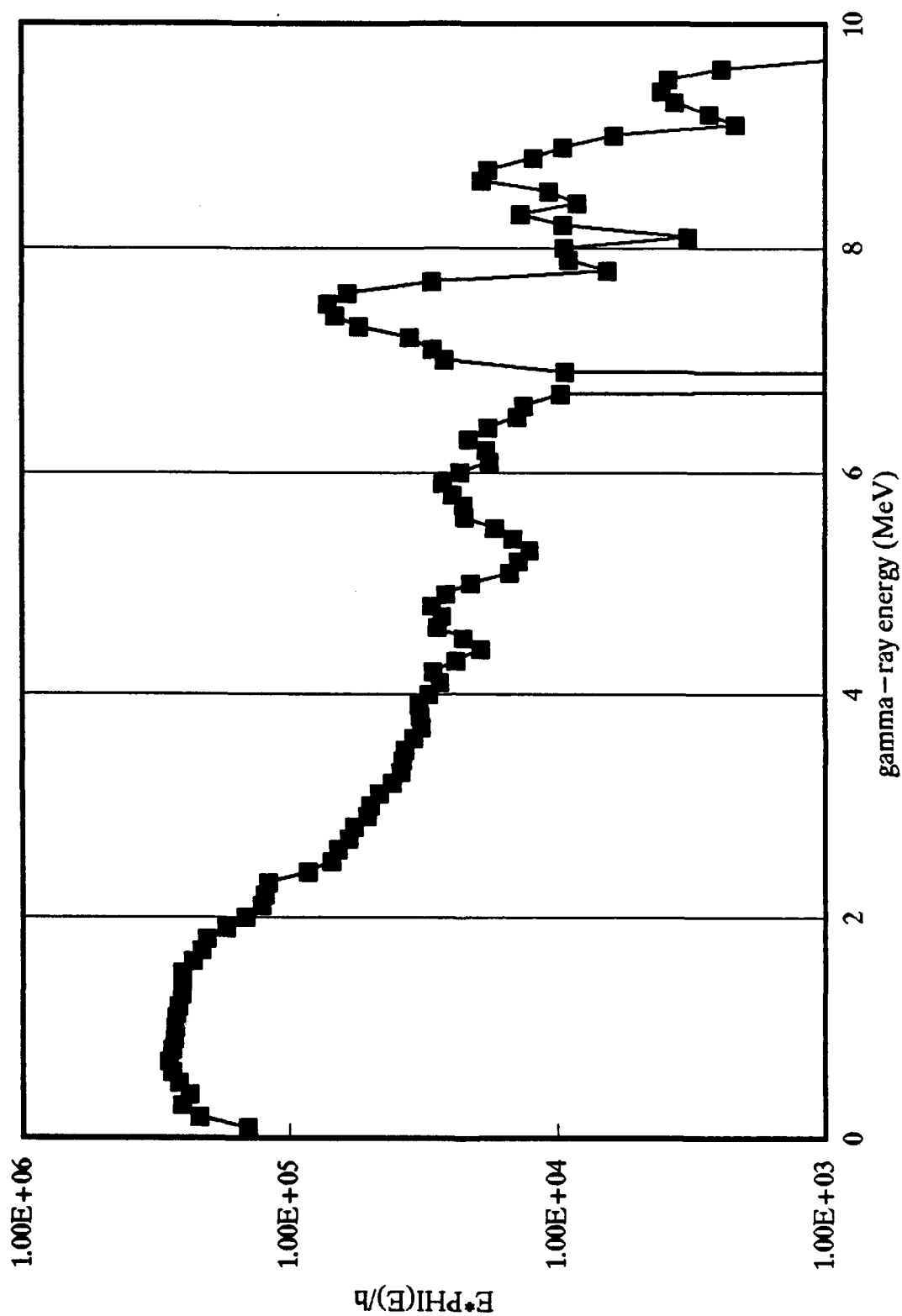


Figure 3: BGO-measured gamma-ray energy spectrum in the area above the RMC SLOWPOKE II facility. Note the presence of peaks (due to neutron capture) riding on a continuum.

# TLD RESPONSE

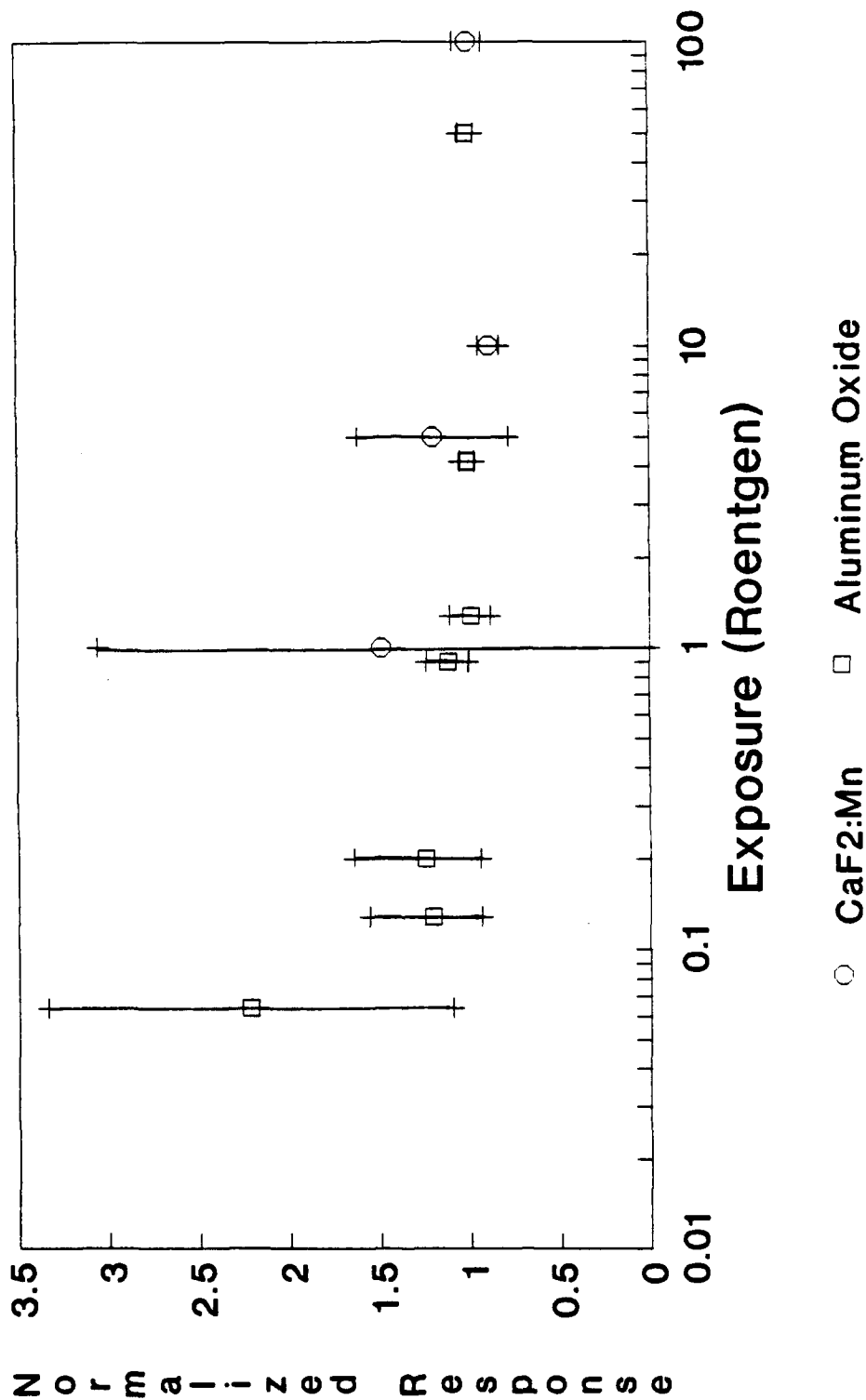
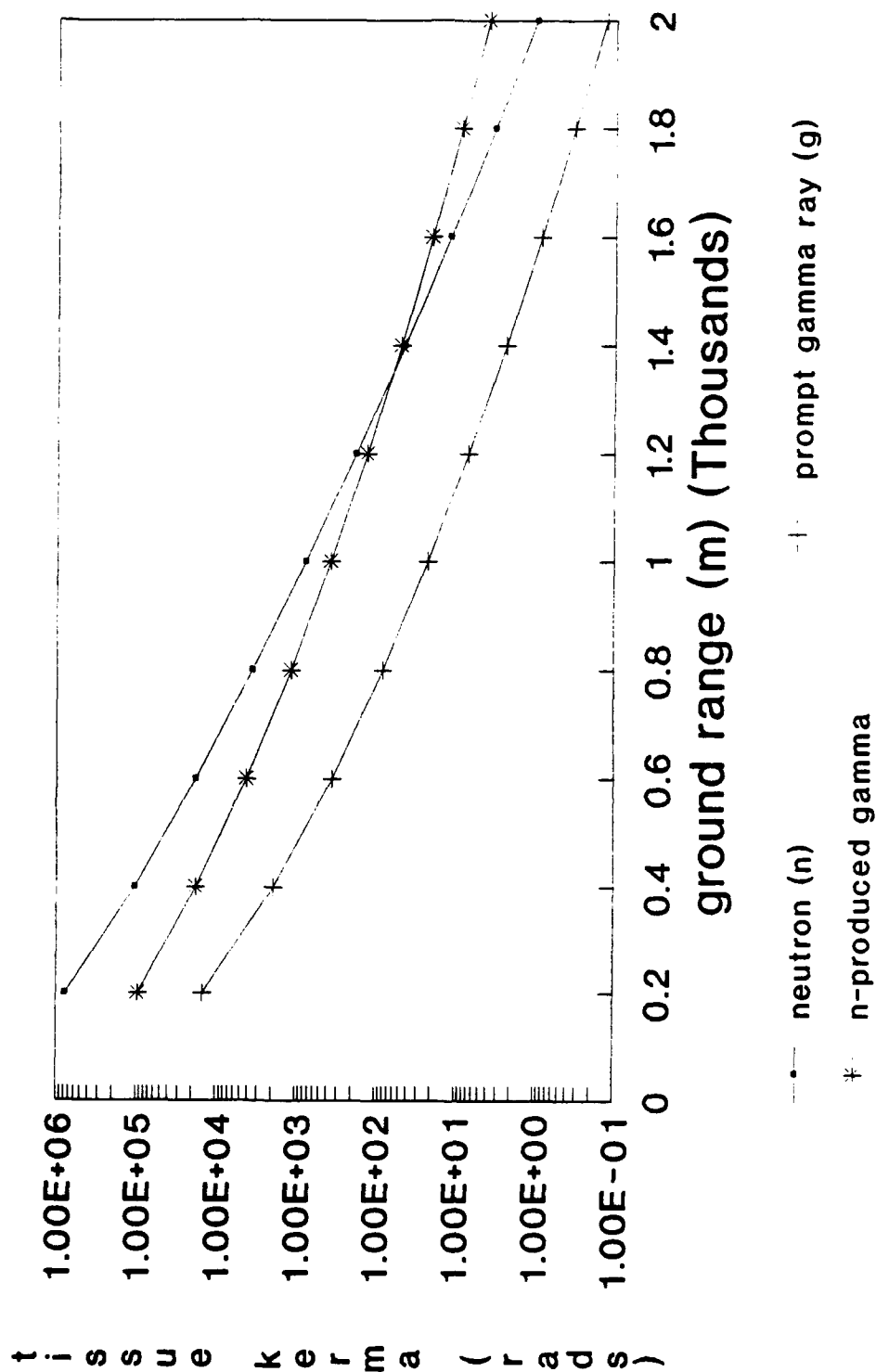


Figure 4: Gamma-ray dosimetric capabilities of DREO TLD systems. A 'perfect' dosimeter here would have a flat (=1) response, with small error bars. Note that with Al<sub>2</sub>O<sub>3</sub> the measurable limit (defined as 10% accuracy) has been reduced from ~ 10 mRad to ~ 0.2 mRad.

# 10 kT SFW BURST



optimum HOB = 129 m

Figure 5: ATR5 output prediction of prompt nuclear radiation from a 10kT standard fission weapon.

# FALLOUT FROM 1 MT WEAPON 10 MPH WIND

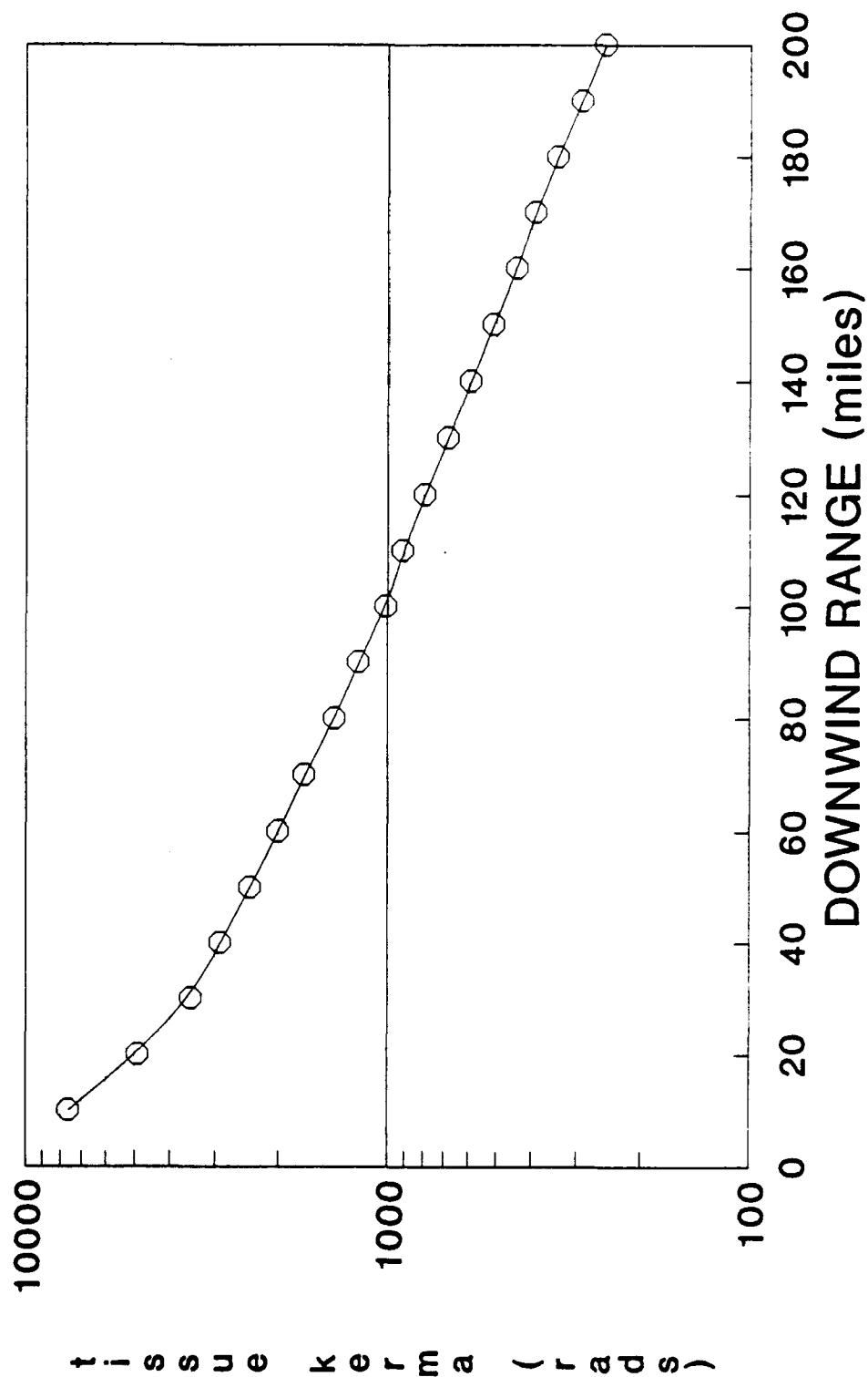


Figure 6: 'Weapons Effects' output prediction of long-range fallout from a 1 MT standard fission weapon.

#### 4.0 REFERENCES

- (1) Robitaille, H.A., S.J. Armour, and T. Cousins, "Residual Radioactive Contamination Resulting from a 1951 Fission-Product Experiment at Defence Research Establishment Suffield". CRAD Report, Sept 1989.
- (2) Cousins, T., B.E. Hoffarth, and K. Jaansalu, "Measurement of the Radiation Fields around the Radiography Facility of the SLOWPOKE II reactor at Royal Military College, Kingston". DREO Report, to be published.
- (3) Cousins, T., and D.C. Kaul, "Review of Current Status of Experimental Results and Theoretical Calculations for Phantom Work at APG". Proceedings of 1989 Workshop of the RSG Physical Dosimetry Subcommittee, ETCA, Arcueil, France, April 1989.
- (4) Cousins, T., B. Jeske, and J.R. Brisson, "Reduction of the DREO Measurable Lower Gamma-Ray Dose Limit". DREO Technical Note, to be published.
- (5) Cousins, T., H. Ing, and K. Tremblay, "Adaptation of the Bubble Detector to the Measurement of Intense Neutron Radiation Fields". IEEE Transactions on Nuclear Science, Vol. 37, No. 6, Dec. 1990, pp.1769-1765.
- (6) Ing, H., and W.G. Cross, "A Criticality Neutron Dosimeter using the  $^{103m}\text{Rh}$  Reaction". Health Physics 25 (1973) pp.291-297.
- (7) Cousins, T., B.E.Hoffarth, H. Ing, and K. Tremblay, "Recent Re-measurement of the Neutron and Gamma-Ray Fields at Large Distances from a Prompt Critical Facility". DREO Report 1031, April 1990.
- (8) Ing, H., and K. Tremblay, "To Develop a Set of Variable Lower-Energy Threshold Bubble Neutron Detectors for Use as a Spectrometer". Bubble Technology Industries Report #BTI-88/2-29A, Feb. 1988 (DND Contract W7714-7-5263).
- (9) Cousins, T., and F.J. LeMay, "An Examination of Possible Low-Mass Critical Assemblies" (C). DREO Report # 1085, Sep. 1991.
- (10) Cousins, T., "The Use of the Computer Code ATR to Relate DREO Experimental Results to Nuclear Battlefield Threats". DREO Technical Note 89-10, Feb. 1989.
- (11) Jamieson, T.J., "Latest Version of VPF". Proceedings of the 1989 Workshop of the RSG-5 Physical Dosimetry Subcommittee, ETCA, Arcueil, France, April, 1989.

UNCLASSIFIED

-15-

SECURITY CLASSIFICATION OF FORM  
(highest classification of Title, Abstract, Keywords)

**DOCUMENT CONTROL DATA**

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

<b>1. ORIGINATOR</b> (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence Research Establishment Ottawa Ottawa, Ontario K1A 0Z4		<b>2. SECURITY CLASSIFICATION</b> (overall security classification of the document including special warning terms if applicable)  <b>UNCLASSIFIED</b>	
<b>3. TITLE</b> (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)  THE NEW DREO MOBILE NUCLEAR LABORATORY (U)			
<b>4. AUTHORS</b> (Last name, first name, middle initial) COUSINS, T. AND HOFFARTH, B.			
<b>5. DATE OF PUBLICATION</b> (month and year of publication of document) JANUARY 92		<b>6a. NO. OF PAGES</b> (total containing information. Include Annexes, Appendices, etc.) 13	<b>6b. NO. OF REFS</b> (total cited in document) 11
<b>7. DESCRIPTIVE NOTES</b> (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.) DREO Technical Note			
<b>8. SPONSORING ACTIVITY</b> (the name of the department project office or laboratory sponsoring the research and development. Include the address.) NUCLEAR EFFECTS SECTION			
<b>9a. PROJECT OR GRANT NO.</b> (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) PROJECT 031LE		<b>9b. CONTRACT NO.</b> (if appropriate, the applicable number under which the document was written)	
<b>10a. ORIGINATOR'S DOCUMENT NUMBER</b> (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) DREO TECHNICAL NOTE 92-6		<b>10b. OTHER DOCUMENT NOS.</b> (Any other numbers which may be assigned this document either by the originator or by the sponsor)	
<b>11. DOCUMENT AVAILABILITY</b> (any limitations on further dissemination of the document, other than those imposed by security classification)  <input checked="" type="checkbox"/> (X) Unlimited distribution <input type="checkbox"/> ( ) Distribution limited to defence departments and defence contractors; further distribution only as approved <input type="checkbox"/> ( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved <input type="checkbox"/> ( ) Distribution limited to government departments and agencies; further distribution only as approved <input type="checkbox"/> ( ) Distribution limited to defence departments; further distribution only as approved <input type="checkbox"/> ( ) Other (please specify):			
<b>12. DOCUMENT ANNOUNCEMENT</b> (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). however, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.) Unlimited Announcement			

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

RA.W (17 Dec 90)

**UNCLASSIFIED**  
SECURITY CLASSIFICATION OF FORM

13. **ABSTRACT** (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

The new DREO Mobile Nuclear Laboratory (MNL) has just recently completed successful field trials. The capabilities of the new MNL are examined, and seen to be far superior to its predecessor. This lab will help keep DREO at the forefront of nuclear radiation research within the NATO community for many years to come.

14. **KEYWORDS, DESCRIPTORS or IDENTIFIERS** (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Nuclear Radiation  
Neutron  
Gamma Ray  
Dosimetry  
Spectroscopy  
Computer Codes